Antioxidant Properties of Strawberry Vinegar

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***Abstract*—Consumption of the strawberry is not only a healthy choice but also enjoyable for most of the people. It is one of the most popular and well-known fruits around the world. It is used to produce pastry products and jam. However, its utilization as vinegar is not a common application. The purpose of this study was to determine chemical properties of strawberry vinegar including antioxidant capacity. For this purpose, total acidity, pH, dry matter content and antioxidant capacity tests such as TEAC, ORAC and total phenolic contents, phenolic compounds and organic acid content analyses were carried out. The pH, total acidity and dry matter contents for strawberry vinegar were 3.57±0.0, 4.59±0.1 and 2.06±0.11, respectively. The TEAC and ORAC values for the vinegar were 6,26 mM TE/g sample, 1.67µmol/ml, respectively. The results of the study indicated that antioxidant properties of strawberry decreased during vinegar fermentation. Also, strawberry vinegar has a "mild" antioxidant activity level when compared with other types of vinegar.**

***Index Terms*—strawberry, strawberry vinegar, strawberry juice, TEAC, ORAC, antioxidant activity**

I. Introduction

The strawberry (*Fragaria x ananassa* Duch.) is one of the genera which belongs to berry fruit group, Rosales order, Rosaceae family and Fragaria species [1]. Turkey ranked as the 5th country around the world in aspect of strawberry production area with 13,423 ha area in 2014. Also, Turkey ranked as the 4th country around the world in aspect of strawberry production amount with 376,070 tones in 2014. Moreover, the exportation amount of strawberry for Turkey was 19,553 tone and 25 million $ U.S. in 2013 [1].

Strawberry is widespread in the Mediterranean region. Even, the fruit has been well-known since the ancient age. The fruit has been used as folk medicine because of its astringent, diuretic and antiseptic properties [2].

It is a source for essential nutrients and useful phytochemicals such as ellagic acid, anthocyanins, quercetin, and catechin. Also, it is a great source of Vitamins C and E. Some recent studies reported that a relation between consumption of strawberry and improved cardiovascular (CV), antiproliferative, and neurologic health aspects [3], [4]. Phenolic compounds in strawberry which historically has received most attention, is the anthocyanins. Anthocyanins have responsible for the bright red colour of the berry groups. The concentration and composition of anthocyanins occurs sensory quality of fruits. Other phenolic compound groups of strawberry are hydrolysable tannins [5]. Phenolic compounds are determined using different methods and methods.

Vinegar is a popular foodstuff around the World. Recent studies have shown its beneficial effects on some important health parameters such as blood-pressure, CV and obesity. Different types of vinegar are rich in some important bioactive compounds such as melanoidines, fructooligosaccharides, phenolic compounds, minerals, vitamins, and α-glucan [6].

Strawberry vinegar has gained importance in recent time and studied from different scientists to determine its ideal production parameters [7], optimize the production parameters [8], determine the odour active compounds [9], determine the effects of different production processes on the product [4], [10], [11]. Also, according to Ebihara and Nakajima [12], strawberry vinegar has modulator effects on blood-glucose and serum-insulin. The purpose of the research was to determine the chemical properties of strawberry vinegar including its antioxidant capacity.

II. Material & Method

A. Vinegar and Juice Production

Fresh strawberries obtained from the markets in Isparta, Turkey. For the juice samples, spontaneously extracted water from strawberries were used. Traditional surface method was preferred for the production of vinegar. Production method of the vinegar was presented in Fig. 1 which was derived from [13].

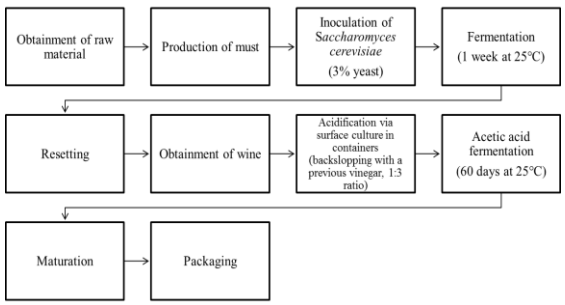

Figure 1. The production method of strawberry vinegar.

B. Chemical Analysis

Strawberry juice and strawberry vinegar samples were tested to determine titration acidity, pH (schott

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instruments ph-meter lab 850, USA) and dry matter analysis (Shimadzu MOC63u UniBloc Moisture Analyzer, Japan) [14].

C. Antioxidant Activity Analysis

Total antioxidant capacity of samples were determined by oxygen radical absorbance capacity (ORAC; Biotek Synergy™ HT Multi-Detection Microplate Reader, Winooski, Vermont, USA) and trolox equivalent antioxidant capacity (TEAC; Boeco Model S-20 Visible Range Spectrophotometer, Germany) [15], [16].

D. Main Phenolic and Organic Acid Compound Analysis

Organic acid and phenolic content of strawberry vinegar determined by HPLC (Shimadzu SCL-10A, Scientific Instruments, Inc., Tokyo, Japonya) which has DAD dedector (LC 20ADvp), pump (LC 10ADvp), gas separator (DGU 20A) and colon oven (CTO 10Avp). To determine phenolic compounds Gemini C18 (150x3 mm, 5 µm, 110A, Phenomenex) colon used. For organic acid content Inertsil ODS 3V (4.8x250 mm 5 µm) colon used.

III. Results & Discussion

A. Chemical Analysis Results

Chemical properties, .e.g., pH, total acidity and dry matter content of strawberry juice and vinegar present in Table I. According to results of our study, pH values were 3.66±0.02 and 3.57±0.0 for strawberry juice and vinegar, respectively. Total acidity values were 0.98±0.35 and 4.59±0.1 g/100 ml for strawberry juice and vinegar, respectively.

TABLE I. Chemical Properties of Strawberry Juice and Vinegar

Parameter	Strawberry Juice	Strawberry Vinegar
Ph	3.66 ±0.02	3.57 ±0.2
Total Acidity (g/100 ml)	0.98 ±0.35	4.59 ±0.1
Dry Matter (g/100g)	7.97 ±0.37	2.06 ±0.11

*The results were given as mean ±standart deviation

A study [17] determined the optimum dosage amount of auxiliary clarifying agents utilized in hot clarification method for pomegranate and strawberry juices. In this study, before clarification, pH value of the strawberry determined as 3.49±0.01 and total acidity as 0.22±0.00 g/100 ml.

Alterations in amount of polyphenols, ascorbic acid and antioxidant activity during process and storage of strawberry juice concentrate was studied by [18]. During this study, pH of strawberry juices changed between 3.35-3.39 based on process step. Also, titration acidity of strawberry juices changed between 0.99-0.94 g/100 ml as dried citric acid.

Our pH and titration acidity results for strawberry juice and vinegar were in range of the literature. Our dry matter contents of strawberry juice and vinegar were 7.97±0.37 and 2.06±0.11 g/100g, respectively. Dry matter contents were also in the range of literature for both of our samples. However, our dry matter content; 2.06±0.11, for vinegar was less than the investigated literature except apple cider vinegar; 1.51±0.15, studied by Zakariaa and Mokhtarb [19].

B. Antioxidant Activity

Antioxidant activity (TEAC and ORAC) of strawberry juice and vinegar present in Table II. The TEAC values of our strawberry juice and vinegar samples were 10.77 and 6.26 mM, respectively. ORAC values were 2.83 and 1.67 µmol/mL, respectively. In addition, our results were summerized in Fig. 2.

TABLE II. Antioxidant Activity (TEAC and ORAC) of Strawberry Juice and Vinegar.

Parameter	Strawberry Juice	Strawberry Vinegar
TEAC (mM)	10.77 ±0.15	6.26 ±0.20
ORAC (µmol/mL)	2.83 ±0.11	1.67 ±0.10

*The results were given as mean ±standart deviation

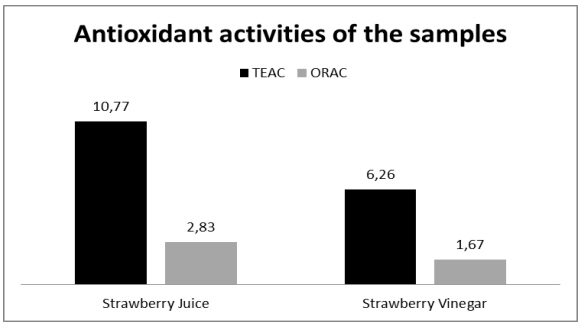

Figure 2. Antioxidant activities of strawberry juice and vinegar

Tulipani, Mezzetti [20] tested 9 different types of strawberry to determine their antioxidant activities. Their TEAC antioxidant values changed between 11–19 mmol TE/g sample. Also, [18] determined the antioxidant activity of juices produced by using 14 different types of strawberries based on ORAC method as 11.9–14.1 µmol TE/g sample.

Different types of vinegar (apple, honey, melon, pomegranate, watermelon, etc.) have tested for their antioxidant activities (ORAC and TEAC). ORAC values changed between 1,068-28,58 µmol/mL [21].

A study carried out by [22] tested 19 different balsamic vinegar to understand the relationship of their physical, chemical and sensorial properties. Also, in this study, antioxidant activities was measured as TEAC values and found as 14,5-58,2 mM TE.

Sour cherry vinegar tested for alterations of its antioxidant and bioactive components during its processing steps. ORAC value of sour cherry juice determined as 4.57 µmol/mL and TEAC values of sour cherry determined as 9.60 mM. For concentrated sour cherry 9.69 µmol/mL and 26.93 mM determined for ORAC and TEAC values, respectively [22]. In the same study [22], sour cherry vinegar tested for ORAC and TEAC. The results were 6.86 µmol/mL and 8.14 mM for ORAC and TEAC tests, respectively.

According to [23] traditional wine vinegar had higher antioxidant activity than commercial wine vinegar. In this study, levels of ORAC and TEAC were 10.50 µmol/mL TE and 13.50 mmol/L TEAC for traditional wine vinear,

respectively. On the other hand, these values were 8.84 µmol/mL TE and 10.37 mmol/L TEAC for commercial wine vinegar, respectively [24].Our results were lower than this study results.

C. Organic Acid Compounds

The results of organic acid compound analysis of strawberry vınegar present in Table III. According to our knowledge, organic acid content has not been studied before.

TABLE III. ORGANIC ACID COMPOUNDS OF STRAWBERRY VINEGAR

Oxalic acid (mg/L)	Citric acid (mg/L)	Malic acid (mg/L)	Lactic acid (mg/L)	Acetic acid (mg/L)
355.5 ±20.2	45.41 ±0.05	492.9 ±2.30	440.9 ±5.40	80798,4 ± 10.30

The results were given as mean ± standart deviation

Budak [25] stated that tartaric acid, malic acid, lactic acid, acetic acid, citric acid, succinic acid of apple vinegar were determined 1272,03 mg/L, 684,16 mg/L, 764,10 mg/L, 68532,70 mg/L, 99,66 mg/L, 255,56 mg/L, respectively. Tartaric acid, lactic acid, acetic acid, citric acid, succinic acid of grape vinegar were determined 2010,80 mg/L, 419,43 mg/L, 85262,8 mg/L, 421,73 mg/L, 1324,26 mg/L, respectively.

D. Phenolic Compounds

The results of the phenolic compound analysis of strawberry vinegar present in Table IV. Gallic acid, chlorogenic acid, catechin, epicatechin has been identified in strawberry vinegar.

TABLE IV. PHENOLIC COMPOUNDS OF STRAWBERRY VINEGAR

Gallic Acid (mg/L)	Chlorogenic Acid (mg/L)	Catechin (mg/L)	Epicatechin (mg/L)
211.42 ±0.59	13.25 ±0.02	10.53 ±0.03	9.57 ±0.06

The results were given as mean ± standart deviation

IV. CONCLUSION

Types of fruits affect the chemical properties of vinegar as well as antioxidant properties. All these values may have an effect on not only its commerciality but also usefullness due to health benefits. In this study, some chemical properties (pH, total acidity, dry matter content) of strawberry juice and traditional strawberry vinegar were determined. The chemical properties were in range of other types of vinegar. For this reason, the chemical properties of strawberry juice may acceptable for the industry and consumers. Strawberry is well-known for its antioxidant properties. Moreover, according to available data present in this study, strawberry vinegar has lower antioxidant activity, too. Strawberry vinegar may think as an alternative product for food industry since the shelf-life of raw strawberry is short. Also, it intensely contains smell and aroma of strawberry. For this reason, it could be an attractive product for consumers. Strawberry vinegar is a value-added and a novel product for the market. Furthermore, providing novel fermented food products with distinct properties by using different types of fruits to consumers may contribute to economy of our country.

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